ARMY RESEARCH LABORATORY

Blast Parameters From *Explosions in Air* (Coded in C++)

by Robert J. Yager

ARL-TN-588 December 2013

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Aberdeen Proving Ground, MD 21005-5066

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Weapons and Materials Research Directorate, ARL

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This report describes a set of arrays, coded in C++, that stores information contained in *Explosions in Air* tables 6-3, 6-4, 6-5, and 6-6. The purpose of the code is to provide model developers with easy access to the tabulated values, which can be used to construct blast pressure histories.

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1. Introduction

This report describes a set of arrays, coded in C++, that stores information contained in the U.S. Army Materiel Command book *Engineering Design Handbook, Explosions in Air*,[1] tables 6-3, 6-4, 6-5, and 6-6. The purpose of the code is to provide model developers with easy access to the tabulated values, which can be used to construct blast pressure histories.

The symbols used in this report are the same as the symbols used in chapter 6 of *Explosions in Air* and, thus, have the same definitions.

2. Tabulated Blast Parameters

Table 1 presents blast parameters obtained from tables 6-3, 6-4, 6-5, and 6-6 of *Explosions in Air*. Noncolored cells contain values that were taken directly from *Explosions in Air*. Colored cells contain interpolated, extrapolated, or modified values.

Green cells contain interpolated values. Interpolations were performed such that they are linear on a log-log plot.

Orange cells contain values that are not meant to be reliable estimations. The values contained in the orange cells are all set to 1.0×10^9. Setting the unknown values to extremely large values was done to assist programmers with the task of testing cell values for validity.

Yellow cells contain extrapolated values that are meant to be reliable estimations. *Explosions in Air* does not list tabulated $\bar{I}_r$ values for $\bar{R} < 0.06$. However, *Explosions in Air* figure 6-3 presents graphical data for $\bar{I}_r$ well below $\bar{R} = 0.06$. The data point $\bar{I}_r = 53$ at $\bar{R} = 0.01423$ was estimated based on figure 6-3. $\bar{I}_r$ values for $0.01423 < \bar{R} < 0.06$ were found by interpolating between $\bar{I}_r$ at $\bar{R} = 0.01423$ and $\bar{I}_r$ at $\bar{R} = 0.06$. Interpolations were performed such that they are linear on a log-log plot.

Blue cells contain modified values.

There appears to be an error in the tabulated values given in table 6-3. For $\bar{R} = 0.016$, $\bar{u}_s$ is stated to be 31.5. However, 31.5 is inconsistent with neighboring values; 21.5 seems likely to be the correct value.

---

[1] U.S. Army Materiel Command. *Engineering Design Handbook, Explosions in Air, Part One*; AMCP 706-181; U.S. Government Printing Office: Alexandria, VA, 1974.

Explosions in Air lists the value for $\bar{t}_a$ at $\bar{R} = 0.01423$ as exactly zero. It is common to work with logarithms of blast parameters, such as when graphing or interpolating. To avoid problems with attempting to find the logarithm of zero, at $\bar{R} = 0.01423$, $\bar{t}_a$ has been set to 1.0×10^{-20}.

Table 1. Blast parameters obtained from tables 6-3, 6-4, 6-5, and 6-6 of *Explosions in Air*.

	Table 6-3							**Table 6-4**			**Table 6-5**				**Table 6-6**
$\bar{R}$	$\bar{P}_s$	$\bar{u}_s$	$\bar{U}$	$\bar{t}_a$	$\bar{\rho}_s$	$\bar{Q}$	$\bar{\theta}_s$	$\bar{P}_r$	$\bar{\rho}_r$	$\bar{\theta}_r$	$\bar{I}_s$	$\bar{I}_r$	$\bar{T}_s$	$\bar{T}_r$	b
.01423	819	23.2	25.2	1E-20	12.18	4570	39.9	1E+9	1E+9	1E+9	1E+9	53	1E+9	1E+9	1E+9
.016	703	21.5	23.6	.0000716	11.9	3850	36.7	1E+9	1E+9	1E+9	1E+9	42.034	1E+9	1E+9	1E+9
.018	605	19.8	21.9	.000166	11.6	3240	34.7	1E+9	1E+9	1E+9	1E+9	33.301	1E+9	1E+9	1E+9
.020	531	18.6	20.6	.000258	11.3	2760	33.1	1E+9	1E+9	1E+9	1E+9	27.038	1E+9	1E+9	1E+9
.030	324	14.4	16.1	.000805	10.1	1450	26.0	1E+9	1E+9	1E+9	1E+9	12.128	1E+9	1E+9	1E+9
.040	225	12.0	13.5	.00148	9.28	935	21.1	1E+9	1E+9	1E+9	1E+9	6.8666	.0206	1E+9	1E+9
.050	170	10.4	11.7	.00227	8.88	670	17.7	1E+9	1E+9	1E+9	1E+9	4.4169	.0184	1E+9	1E+9
.0538	154.29	9.8912	11.163	.0025799	8.6622	591.18	16.637	1840	1E+9	1E+9	1E+9	3.8213	.018033	1E+9	1E+9
.060	133.54	9.1794	10.408	.0031215	8.3476	490.67	15.171	1492.3	1E+9	1E+9	1E+9	3.08	.0175	.0140	1E+9
.070	108.88	8.2599	9.4284	.0040863	7.9225	377.06	13.317	1110	1E+9	1E+9	1E+9	2.3506	.0175	.016018	1E+9
.080	91.240	7.5381	8.6543	.0051599	7.5718	300.14	11.895	860	37.8	20.7	1E+9	1.86	.0175	.0180	1E+9
.100	67.9	6.47	7.50	.00762	7.02	205	9.85	585	33.2	16.8	.0785	1.27	.0191	.0219	15.5
.150	37.2	4.61	5.55	.0154	5.91	87.2	6.20	277	24.4	12.1	.0788	.677	.0341	.0315	15.0
.200	20.4	3.50	4.27	.0255	4.92	44.1	4.31	146	18.1	7.46	.106	.456	.0885	.0425	16.0
.250	11.9	2.69	3.33	.0382	4.20	20.8	3.21	80.3	13.5	5.15	.103	.355	.157	.0542	17.0
.300	7.28	1.95	2.66	.0541	3.59	9.45	2.48	37.7	10.0	3.71	.0885	.294	.171	.0684	12.9
.400	3.46	1.25	2.00	.0990	2.66	2.79	1.68	15.3	6.10	2.42	.0695	.222	.158	.103	6.76
.500	2.05	.888	1.67	.157	2.09	1.08	1.43	9.40	4.16	1.90	.0570	.178	.162	.147	4.56
.600	1.38	.672	1.48	.218	1.81	.570	1.30	6.05	3.14	1.65	.0482	.150	.181	.195	3.87
.800	.772	.427	1.28	.340	1.49	.212	1.18	2.63	2.12	1.39	.0371	.112	.232	1E+9	3.48
1.00	.506	.302	1.19	.466	1.33	.0940	1.12	1.31	1.66	1.26	.0302	.0885	.268	1E+9	3.08
1.50	.254	.165	1.11	.830	1.17	.0196	1.07	.580	1.32	1.13	.020674	.053722	.31953	1E+9	2.5230
2.00	.161	.107	1.0733	1.26	1.11	.00758	1.0436	.358	1.22	1.0880	.0158	.0377	.362	1E+9	2.19
2.50	.115	.0797	1.0481	1.71	1.0809	.00423	1.0306	.250	1.16	1.0612	.012752	.029338	.38687	1E+9	2.0597
3.00	.0889	.0631	1.0374	2.20	1.0628	.00270	1.0247	.188	1.12	1.0594	.010704	.023903	.40846	1E+9	1.9590
4.00	.0616	.0441	1.0257	3.21	1.0436	.00137	1.0172	.126	1.0870	1.0344	.00812	.0173	.445	1E+9	1.81
5.00	.0468	.0336	1.0198	4.21	1.0332	.000820	1.0134	.0948	1.0664	1.0268	.0065268	.013618	.47186	1E+9	1.8264
6.00	.0374	.0268	1.0159	5.19	1.0266	.000515	1.0107	.0765	1.0532	1.0214	.00546	.0112	.495	1E+9	1.84
8.00	.0261	.0190	1.0111	7.15	1.0186	.000250	1.00745	.0536	1.0392	1.0149	.00410	.0084	.532	1E+9	1.83
10.0	.0198	.0144	1.00850	9.10	1.0141	.000143	1.00565	.0401	1.0282	1.0113	.00325	.00658	.564	1E+9	1.87
20.0	.00870	.00621	1.00372	18.9	1.00620	2.76E-05	1.00248	.0176	1.0124	1.00496	.00158	.00320	.666	1E+9	2.17
30.0	.00543	.00390	1.00232	28.8	1.00387	1.07E-05	1.00155	.0110	1.00774	1.00310	.0010329	.0020862	.73104	1E+9	2.3848
40.0	.00391	.00279	1.00167	38.9	1.00279	5.52E-06	1.00112	.00788	1.00558	1.00224	.000764	.00154	.781	1E+9	2.55
50.0	.00304	.00217	1.00130	48.9	1.00217	3.31E-06	1.000870	.00612	1.00434	1.00174	.00060368	.0012116	.82142	1E+9	2.7214
60.0	.00248	.00177	1.00106	58.8	1.00177	2.19E-06	1.000709	.00496	1.00354	1.00142	.000498	.00100	.856	1E+9	2.87
80.0	.00181	.00128	1.000618	78.5	1.00103	1.15E-06	1.000413	.00358	1.00206	1.000825	.00036940	.00073880	.91310	1E+9	3.0782
100	.00141	.00100	1.000494	98.5	1.000824	6.95E-07	1.000330	.00280	1.00165	1.000660	.000293	.000586	.960	1E+9	3.25
500	.000242	.000173	1.0000988	499	1.000173	2.03E-08	1.000066	.000486	1.000330	1.000132	5.75E-05	.000115	1.24	1E+9	3.90
1000	.0001153	.000082	1.0000494	1000	1.0000824	4.71E-09	1.000033	.000231	1.000165	1.000066	2.88E-05	5.76E-05	1.25	1E+9	3.67

3. C++ Code

The following arrays are used to store the values presented in table 1. Each array stores one column.

3.1 $\overline{R}$ Values: The R Array

```
const double R[39]={//<------------------------------------------SCALED RANGES
  .01423,.016,.018,.02,.03,.04,.05,.0538,.06,.07,.08,.1,.15,.2,.25,.3,.4,.5,
  .6,.8,1,1.5,2,2.5,3,4,5,6,8,10,20,30,40,50,60,80,100,500,1000
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.2 $\overline{P}_s$ Values: The P_s Array

```
const double P_s[39]={//<--------------------SCALED PEAK SIDE-ON OVERPRESSURES
  819,703,605,531,324,225,170,154.29,133.54,108.88,91.24,67.9,37.2,20.4,11.9,
  7.28,3.46,2.05,1.38,.772,.506,.254,.161,.115,.0889,.0616,.0468,.0374,.0261,
  .0198,.0087,.00543,.00391,.00304,.00248,.00181,.00141,.000242,.000115
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.3 $\overline{u}_s$ Values: The u_s Array

```
const double u_s[39]={//<--------------------------SCALED PEAK PARTICLE SPEEDS
  23.2,21.5,19.8,18.6,14.4,12,10.4,9.8912,9.1794,8.2599,7.5381,6.47,4.61,3.5,
  2.69,1.95,1.25,.888,.672,.427,.302,.165,.107,.0797,.0631,.0441,.0336,.0268,
  .019,.0144,.00621,.0039,.00279,.00217,.00177,.00128,.001,.000173,8.2E-5
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.4 $\overline{U}$ Values: The U Array

```
const double U[39]={//<------------------------------------SCALED SHOCK SPEEDS
  25.2,23.6,21.9,20.6,16.1,13.5,11.7,11.163,10.408,9.4284,8.6543,7.5,5.55,
  4.27,3.33,2.66,2,1.67,1.48,1.28,1.19,1.11,1.0733,1.0481,1.0374,1.0257,
  1.0198,1.0159,1.0111,1.0085,1.00372,1.00232,1.00167,1.0013,1.00106,1.000618,
  1.000494,1.0000988,1.0000494
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.5 $\overline{t}_a$ Values: The t_a Array

```
const double t_a[39]={//<---------------------------------SCALED ARRIVAL TIMES
  1E-20,7.16E-5,1.66E-4,2.58E-4,8.05E-4,.00148,.00227,.0025799,.0031215,
  .0040863,.0051599,.00762,.0154,.0255,.0382,.0541,.0990,.157,.218,.34,.466,
  .83,1.26,1.71,2.2,3.21,4.21,5.19,7.15,9.1,18.9,28.8,38.9,48.9,58.8,78.5,
  98.5,499,1000
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.6 $\overline{\rho}_s$ Values: The rho_s Array

```
const double rho_s[39]={//<----------------------SCALED PEAK SIDE-ON DENSITIES
  12.18,11.9,11.6,11.3,10.1,9.28,8.88,8.6622,8.3476,7.9225,7.5718,7.02,5.91,
  4.92,4.2,3.59,2.66,2.09,1.81,1.49,1.33,1.17,1.11,1.0809,1.0628,1.0436,
  1.0332,1.0266,1.0186,1.0141,1.0062,1.00387,1.00279,1.00217,1.00177,1.00103,
  1.000824,1.000173,1.0000824
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.7 $\overline{Q}$ Values: The Q Array

```
const double Q[39]={//<---------------------SCALED PEAK DYNAMIC OVERPRESSURES
  4570,3850,3240,2760,1450,935,670,591.18,490.67,377.06,300.14,205,87.2,44.1,
  20.8,9.45,2.79,1.08,.57,.212,.094,.0196,.00758,.00423,.00270,.00137,.00082,
  .000515,.00025,.000143,2.76E-5,1.07E-5,5.52E-6,3.31E-6,2.19E-6,1.15E-6,
  6.95E-7,2.03E-8,4.71E-9
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.8 $\overline{\theta}_s$ Values: The T_s Array

```
const double T_s[39]={//<---------------------SCALED PEAK SIDE-ON TEMPERATURES
  39.9,36.7,34.7,33.1,26,21.1,17.7,16.637,15.171,13.317,11.895,9.85,6.2,
  4.31,3.21,2.48,1.68,1.43,1.3,1.18,1.12,1.07,1.0436,1.0306,1.0247,1.0172,
  1.0134,1.0107,1.00745,1.00565,1.00248,1.00155,1.00112,1.00087,1.000709,
  1.000413,1.00033,1.000066,1.000033
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.9 $\overline{P}_r$ Values: The P_r Array

```
const double P_r[39]={//<------------------SCALED PEAK REFLECTED OVERPRESSURES
  1E9,1E9,1E9,1E9,1E9,1E9,1E9,1840,1492.3,1110,860,585,277,146,80.3,37.7,15.3,
  9.4,6.05,2.63,1.31,.58,.358,.25,.188,.126,.0948,.0765,.0536,.0401,.0176,
  .0110,.00788,.00612,.00496,.00358,.0028,.000486,.000231
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.10 $\overline{\rho}_r$ Values: The rho_r Array

```
const double rho_r[39]={//<--------------------SCALED PEAK REFLECTED DENSITIES
  1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,37.8,33.2,24.4,18.1,13.5,10,6.1,
  4.16,3.14,2.12,1.66,1.32,1.22,1.16,1.12,1.087,1.0664,1.0532,1.0392,1.0282,
  1.0124,1.00774,1.00558,1.00434,1.00354,1.00206,1.00165,1.00033,1.000165
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.11 $\overline{\theta}_r$ Values: The T_r Array

```
const double T_r[39]={//<-------------------SCALED PEAK REFLECTED TEMPERATURES
  1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,20.7,16.8,12.1,7.46,5.15,3.71,2.42,
  1.9,1.65,1.39,1.26,1.13,1.088,1.0612,1.0594,1.0344,1.0268,1.0214,1.0149,
  1.0113,1.00496,1.0031,1.00224,1.00174,1.00142,1.000825,1.00066,1.000132,
  1.000066
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.12 $\overline{I}_s$ Values: The I_s Array

```
const double I_s[39]={//<---------------------SCALED SIDE-ON SPECIFIC IMPULSES
  1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,.0785,.0788,.106,.103,.0885,
  .0695,.0570,.0482,.0371,.0302,.020674,.0158,.012752,.010704,.00812,.0065268,
  .00546,.00410,.00325,.00158,.0010329,.000764,.00060368,.000498,.0003694,
  .000293,5.75E-5,2.88E-5
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.13 $\bar{I}_r$ Values: The I_r Array

```
const double I_r[39]={//<-------------------SCALED REFLECTED SPECIFIC IMPULSES
  53,42.0339,33.3008,27.0381,12.1279,6.86659,4.41691,3.82133,3.08,2.3506,1.86,
  1.27,.677,.456,.355,.294,.222,.178,.15,.112,.0885,.053722,.0377,.029338,
  .023903,.0173,.013618,.0112,.0084,.00658,.0032,.0020862,.00154,.0012116,
  .000996,.0007388,.000586,.000115,.0000576
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.14 $\bar{T}_s$ Values: The t_s Array

```
const double t_s[39]={//<--------------SCALED SIDE-ON POSITIVE-PHASE DURATIONS
  1E9,1E9,1E9,1E9,1E9,.0206,.0184,.018033,.0175,.0175,.0175,.0191,.0341,.0885,
  .157,.171,.158,.162,.181,.232,.268,.31953,.362,.38687,.40846,.445,.47186,
  .495,.532,.564,.666,.73104,.781,.82142,.856,.9131,.96,1.24,1.25

};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.15 $\bar{T}_r$ Values: The t_r Array

```
const double t_r[39]={//<------------SCALED REFLECTED POSITIVE-PHASE DURATIONS
  1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,.014,.016018,.018,.0219,.0315,.0425,.0542,
  .0684,.103,.147,.195,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,
  1E9,1E9,1E9,1E9,1E9,1E9,1E9
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

3.16 b Values: The b Array

```
const double b[39]={//<----------------------------------------DECAY CONSTANTS
  1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,15.5,15,16,17,12.9,6.76,4.56,
  3.87,3.48,3.08,2.523,2.19,2.0597,1.959,1.81,1.8264,1.84,1.83,1.87,2.17,
  2.3848,2.55,2.7214,2.87,3.0782,3.25,3.9,3.67
};//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

4. Example: Recreating Figure 6-1 From *Explosions in Air*

The following example uses the R, P_s, u_s, U, t_a, rho_s, Q, and T_s arrays to create a text file that contains the information necessary to recreate figure 6-1 from *Explosions in Air*. Figure 1 presents a graph of the contents of the example's output file.

Note that there is an error on the original graph: the far-right label for the $\bar{\theta}_s$ line is given as $10\bar{\theta}_s$.

```
#include <cstdio>//......................FILE,freopen(),stdout,printf(),fclose()
#include "y_blast_eia.h"//............................................yBlastEia
int main(){
  FILE *f=freopen("figure_6_1.csv","w",stdout);
  printf("#R_bar,P_bar_s,10^4*P_bar_s,10*u_bar_s,10^5*u_bar_s,10^2*U_bar,"
    "10*t_bar_a,10^5*t_bar_a,10*rho_bar_s,Q_bar,10^4*Q_bar,10^8*Q_bar,"
    "10^12*Q_bar,theta_bar_s\n");
  for(int i=0;i<39;++i){
    printf("%e,",yBlastEia::R[i]);
    printf("%e,",yBlastEia::P_s[i]);
    printf("%e,",yBlastEia::P_s[i]*1E4);
    printf("%e,",yBlastEia::u_s[i]*10);
    printf("%e,",yBlastEia::u_s[i]*1E5);
    printf("%e,",yBlastEia::U[i]*1E2);
    printf("%e,",yBlastEia::t_a[i]*10);
    printf("%e,",yBlastEia::t_a[i]*1E5);
    printf("%e,",yBlastEia::rho_s[i]*10);
    printf("%e,",yBlastEia::Q[i]);
    printf("%e,",yBlastEia::Q[i]*1E4);
    printf("%e,",yBlastEia::Q[i]*1E8);
    printf("%e,",yBlastEia::Q[i]*1E12);
    printf("%e\n",yBlastEia::T_s[i]);}
  fclose(f);
}//~~~~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

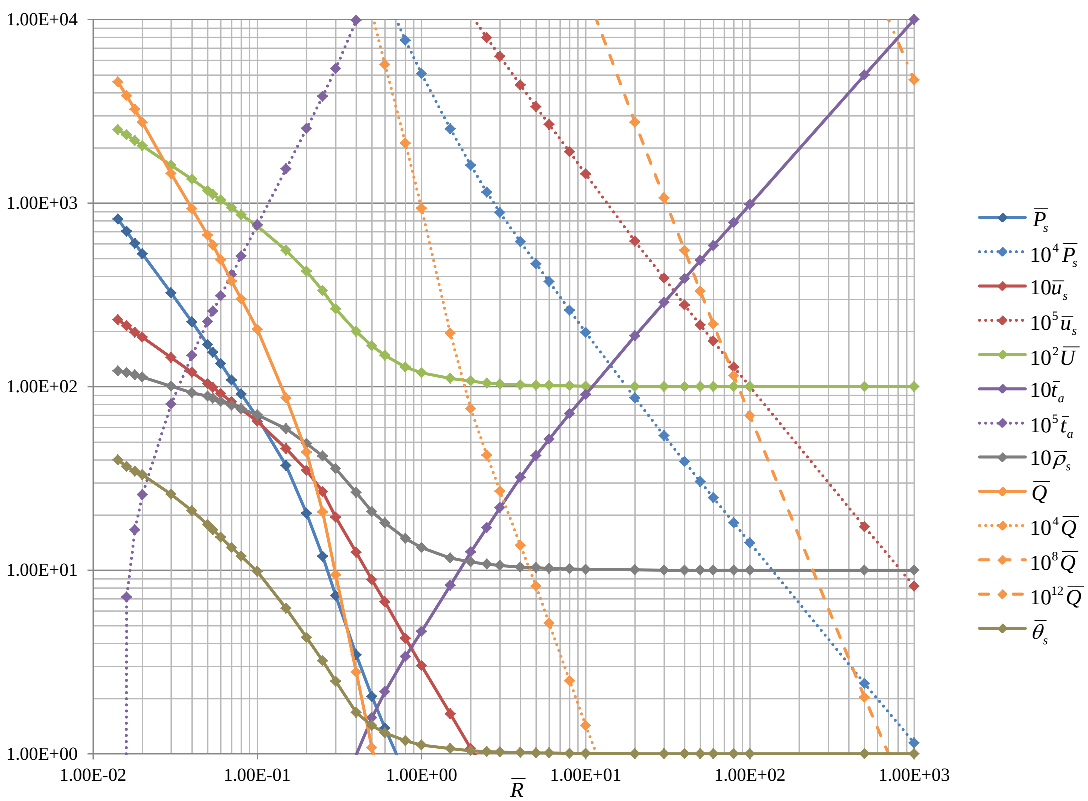


Figure 1. Recreation of figure 6-1 from *Explosions in Air*.

5. Example: Recreating Figure 6-2 From *Explosions in Air*

The following example uses the R, P_r, rho_r, and T_r arrays to create a text file that contains the information necessary to recreate figure 6-2 from *Explosions in Air*. Figure 2 presents a graph of the contents of the example's output file.

```
#include <cstdio>//.....................FILE,freopen(),stdout,printf(),fclose()
#include "y_blast_eia.h"//.........................................yBlastEia
int main(){
  FILE *f=freopen("figure_6_2.csv","w",stdout);
  printf("#R_bar,P_bar_r,10^4*P_bar_r,rho_bar_r,10*theta_bar_r\n");
  for(int i=0;i<39;++i){
    printf("%e,",yBlastEia::R[i]);
    printf("%e,",yBlastEia::P_r[i]);
    printf("%e,",yBlastEia::P_r[i]*1E4);
    printf("%e,",yBlastEia::rho_r[i]);
    printf("%e\n",yBlastEia::T_r[i]*10);}
  fclose(f);
}//~~~~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

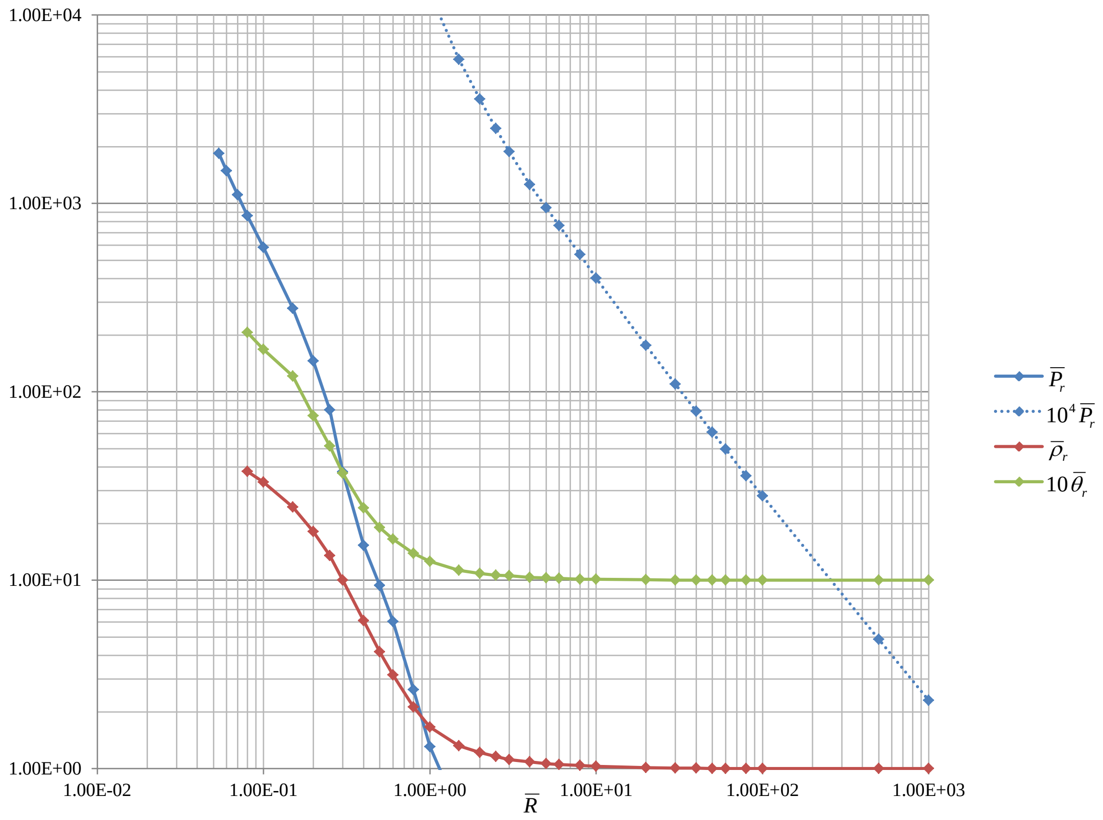


Figure 2. Recreation of figure 6-2 from *Explosions in Air*.

6. Example: Recreating Figure 6-3 From *Explosions in Air*

The following example uses the R, I_s, I_r, t_s, t_r, and b arrays to create a text file that contains the information necessary to recreate figure 6-2 from *Explosions in Air*. Figure 3 presents a graph of the contents of the example's output file.

Note that there is an error on the original graph: the line that is labeled $b\times10^{3}$ should actually be labeled $b\times10^{-3}$.

```
#include <cstdio>//.....................FILE,freopen(),stdout,printf(),fclose()
#include "y_blast_eia.h"//............................................yBlastEia
int main(){
  FILE *f=freopen("figure_6_3.csv","w",stdout);
  printf("#R_bar,I_bar_s,I_bar_s*10^4,I_bar_r*10^-5,I_bar_r*10^-1,I_bar_r*10^3,"
    "T_bar_s*10^-2,T_bar_r*10^-2,b*10^-3\n");
  for(int i=0;i<39;++i){
    printf("%e,",yBlastEia::R[i]);
    printf("%e,",yBlastEia::I_s[i]);
    printf("%e,",yBlastEia::I_s[i]*1E4);
    printf("%e,",yBlastEia::I_r[i]*1E-5);
    printf("%e,",yBlastEia::I_r[i]*1E-1);
    printf("%e,",yBlastEia::I_r[i]*1E3);
    printf("%e,",yBlastEia::t_s[i]*1E-2);
    printf("%e,",yBlastEia::t_r[i]*1E-2);
    printf("%e\n",yBlastEia::b[i]*1E-3);}
  fclose(f);
}//~~~~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

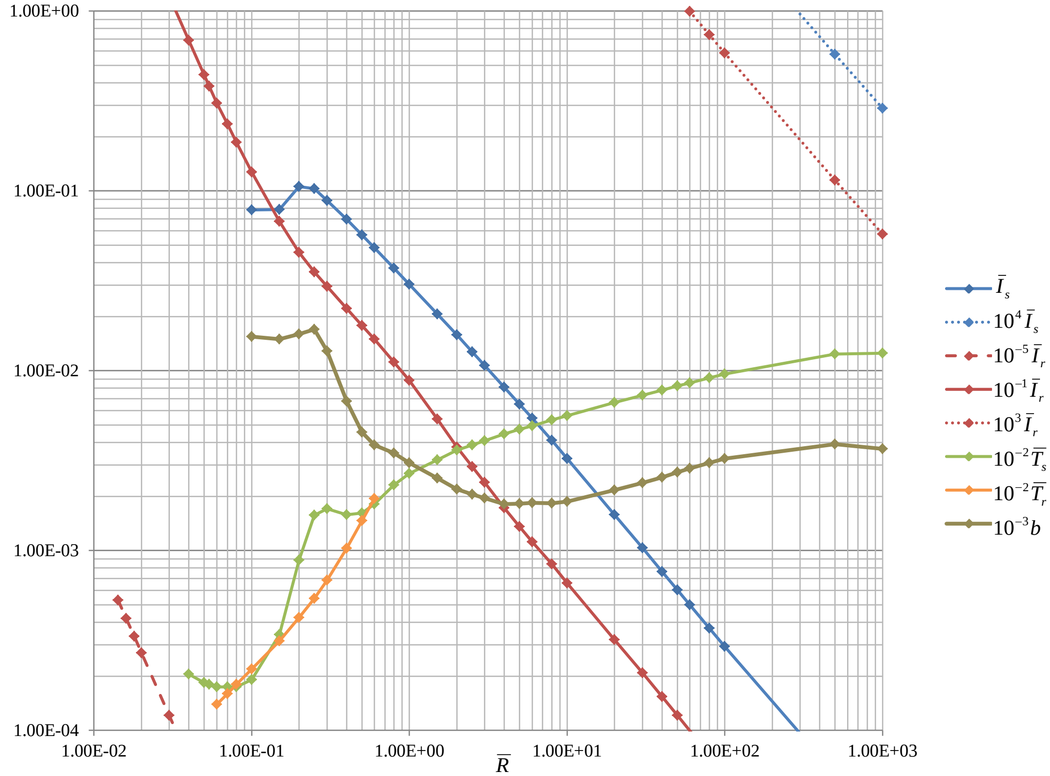


Figure 3. Recreation of figure 6-3 from *Explosions in Air*.

7. Summary

A summary sheet is provided at the end of this report. It presents the yBlastEia namespace, which contains the 16 arrays that are described in this report.

yBlastEia Summary

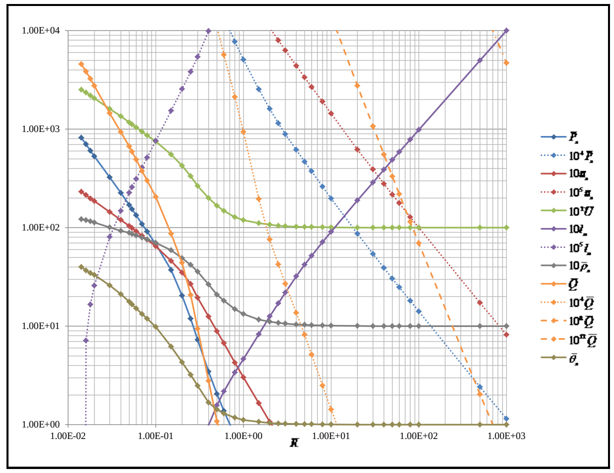
y_blast_eia.h

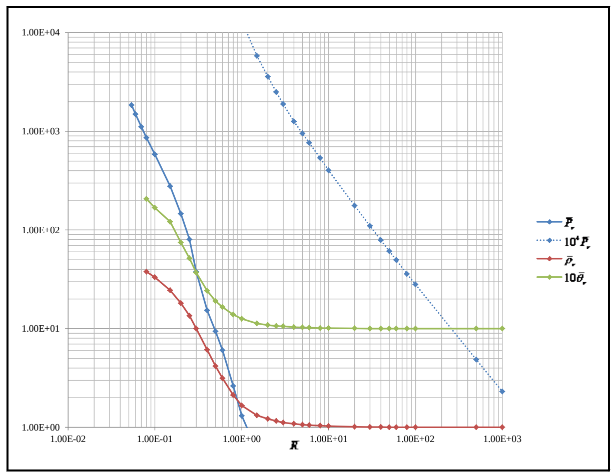
```
#ifndef Y_BLAST_EIA_GUARD//   See Yager, R. J. "Blast Parameters from Explosions
#define Y_BLAST_EIA_GUARD//                           in Air (Coded in C++)"
namespace yBlastEia{//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
  const double R[39]={//<-------------------------------------------SCALED RANGES
    .01423,.016,.018,.02,.03,.04,.05,.0538,.06,.07,.08,.1,.15,.2,.25,.3,.4,.5,
    .6,.8,1,1.5,2,2.5,3,4,5,6,8,10,20,30,40,50,60,80,100,500,1000
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double P_s[39]={//<--------------------SCALED PEAK SIDE-ON OVERPRESSURES
    819,703,605,531,324,225,170,154.29,133.54,108.88,91.24,67.9,37.2,20.4,11.9,
    7.28,3.46,2.05,1.38,.772,.506,.254,.161,.115,.0889,.0616,.0468,.0374,.0261,
    .0198,.0087,.00543,.00391,.00304,.00248,.00181,.00141,.000242,.000115
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double u_s[39]={//<------------------------SCALED PEAK PARTICLE SPEEDS
    23.2,21.5,19.8,18.6,14.4,12,10.4,9.8912,9.1794,8.2599,7.5381,6.47,4.61,3.5,
    2.69,1.95,1.25,.888,.672,.427,.302,.165,.107,.0797,.0631,.0441,.0336,.0268,
    .019,.0144,.00621,.0039,.00279,.00217,.00177,.00128,.001,.000173,8.2E-5
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double U[39]={//<-----------------------------------SCALED SHOCK SPEEDS
    25.2,23.6,21.9,20.6,16.1,13.5,11.7,11.163,10.408,9.4284,8.6543,7.5,5.55,
    4.27,3.33,2.66,2,1.67,1.48,1.28,1.19,1.11,1.0733,1.0481,1.0374,1.0257,
    1.0198,1.0159,1.0111,1.0085,1.00372,1.00232,1.00167,1.0013,1.00106,1.000618,
    1.000494,1.0000988,1.0000494
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double t_a[39]={//<--------------------------------SCALED ARRIVAL TIMES
    1E-20,7.16E-5,1.66E-4,2.58E-4,8.05E-4,.00148,.00227,.0025799,.0031215,
    .0040863,.0051599,.00762,.0154,.0255,.0382,.0541,.0990,.157,.218,.34,.466,
    .83,1.26,1.71,2.2,3.21,4.21,5.19,7.15,9.1,18.9,28.8,38.9,48.9,58.8,78.5,
    98.5,499,1000
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double rho_s[39]={//<----------------------SCALED PEAK SIDE-ON DENSITIES
    12.18,11.9,11.6,11.3,10.1,9.28,8.88,8.6622,8.3476,7.9225,7.5718,7.02,5.91,
    4.92,4.2,3.59,2.66,2.09,1.81,1.49,1.33,1.17,1.11,1.0809,1.0628,1.0436,
    1.0332,1.0266,1.0186,1.0141,1.0062,1.00387,1.00279,1.00217,1.00177,1.00103,
    1.000824,1.000173,1.0000824
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double Q[39]={//<----------------------SCALED PEAK DYNAMIC OVERPRESSURES
    4570,3850,3240,2760,1450,935,670,591.18,490.67,377.06,300.14,205,87.2,44.1,
    20.8,9.45,2.79,1.08,.57,.212,.094,.0196,.00758,.00423,.00270,.00137,.00082,
    .000515,.00025,.000143,2.76E-5,1.07E-5,5.52E-6,3.31E-6,2.19E-6,1.15E-6,
    6.95E-7,2.03E-8,4.71E-9
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double T_s[39]={//<---------------------SCALED PEAK SIDE-ON TEMPERATURES
    39.9,36.7,34.7,33.1,26,21.1,17.7,16.637,15.171,13.317,11.895,9.85,6.2,
    4.31,3.21,2.48,1.68,1.43,1.3,1.18,1.12,1.07,1.0436,1.0306,1.0247,1.0172,
    1.0134,1.0107,1.00745,1.00565,1.00248,1.00155,1.00112,1.00087,1.000709,
    1.000413,1.00033,1.000066,1.000033
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double P_r[39]={//<------------------SCALED PEAK REFLECTED OVERPRESSURES
    1E9,1E9,1E9,1E9,1E9,1E9,1E9,1840,1492.3,1110,860,585,277,146,80.3,37.7,15.3,
    9.4,6.05,2.63,1.31,.58,.358,.25,.188,.126,.0948,.0765,.0536,.0401,.0176,
    .0110,.00788,.00612,.00496,.00358,.0028,.000486,.000231
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double rho_r[39]={//<--------------------SCALED PEAK REFLECTED DENSITIES
    1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,37.8,33.2,24.4,18.1,13.5,10,6.1,
    4.16,3.14,2.12,1.66,1.32,1.22,1.16,1.12,1.087,1.0664,1.0532,1.0392,1.0282,
    1.0124,1.00774,1.00558,1.00434,1.00354,1.00206,1.00165,1.00033,1.000165
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double T_r[39]={//<------------------SCALED PEAK REFLECTED TEMPERATURES
    1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,20.7,16.8,12.1,7.46,5.15,3.71,2.42,
    1.9,1.65,1.39,1.26,1.13,1.088,1.0612,1.0594,1.0344,1.0268,1.0214,1.0149,
    1.0113,1.00496,1.0031,1.00224,1.00174,1.00142,1.000825,1.00066,1.000132,
    1.000066
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double I_s[39]={//<---------------------SCALED SIDE-ON SPECIFIC IMPULSES
    1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,.0785,.0788,.106,.103,.0885,
    .0695,.0570,.0482,.0371,.0302,.020674,.0158,.012752,.010704,.00812,.0065268,
    .00546,.00410,.00325,.00158,.0010329,.000764,.00060368,.000498,.0003694,
    .000293,5.75E-5,2.88E-5
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double I_r[39]={//<-------------------SCALED REFLECTED SPECIFIC IMPULSES
    53,42.0339,33.3008,27.0381,12.1279,6.86659,4.41691,3.82133,3.08,2.3506,1.86,
    1.27,.677,.456,.355,.294,.222,.178,.15,.112,.0885,.053722,.0377,.029338,
    .023903,.0173,.013618,.0112,.0084,.00658,.0032,.0020862,.00154,.0012116,
    .000996,.0007388,.000586,.000115,.0000576
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double t_s[39]={//<--------------SCALED SIDE-ON POSITIVE-PHASE DURATIONS
    1E9,1E9,1E9,1E9,1E9,.0206,.0184,.018033,.0175,.0175,.0175,.0191,.0341,.0885,
    .157,.171,.158,.162,.181,.232,.268,.31953,.362,.38687,.40846,.445,.47186,
    .495,.532,.564,.666,.73104,.781,.82142,.856,.9131,.96,1.24,1.25
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double t_r[39]={//<------------SCALED REFLECTED POSITIVE-PHASE DURATIONS
    1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,.014,.016018,.018,.0219,.0315,.0425,.0542,
    .0684,.103,.147,.195,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,
    1E9,1E9,1E9,1E9,1E9,1E9,1E9
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
  const double b[39]={//<-------------------------------------------DECAY CONSTANTS
    1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,1E9,15.5,15,16,17,12.9,6.76,4.56,
    3.87,3.48,3.08,2.523,2.19,2.0597,1.959,1.81,1.8264,1.84,1.83,1.87,2.17,
    2.3848,2.55,2.7214,2.87,3.0782,3.25,3.9,3.67
  };//~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
}//@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
#endif
```

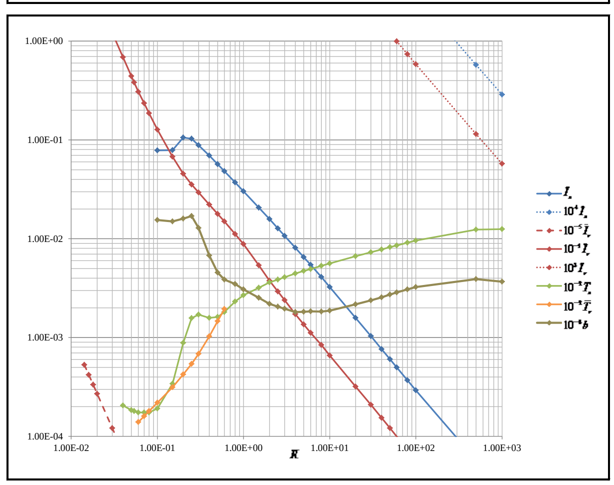
Example - Recreating EIA Figure 6-1

```
#include <cstdio>//.....................FILE,freopen(),stdout,printf(),fclose()
#include "y_blast_eia.h"//..........................................yBlastEia
int main(){
  FILE *f=freopen("figure_6_1.csv","w",stdout);
  printf("#R_bar,P_bar_s,10^4*P_bar_s,10*u_bar_s,10^5*u_bar_s,10^2*U_bar,"
    "10*t_bar_a,10^5*t_bar_a,10*rho_bar_s,Q_bar,10^4*Q_bar,10^8*Q_bar,"
    "10^12*Q_bar,theta_bar_s\n");
  for(int i=0;i<39;++i){
    printf("%e,",yBlastEia::R[i]);
    printf("%e,",yBlastEia::P_s[i]);
    printf("%e,",yBlastEia::P_s[i]*1E4);
    printf("%e,",yBlastEia::u_s[i]*10);
    printf("%e,",yBlastEia::u_s[i]*1E5);
    printf("%e,",yBlastEia::U[i]*1E2);
    printf("%e,",yBlastEia::t_a[i]*10);
    printf("%e,",yBlastEia::t_a[i]*1E5);
    printf("%e,",yBlastEia::rho_s[i]*10);
    printf("%e,",yBlastEia::Q[i]);
    printf("%e,",yBlastEia::Q[i]*1E4);
    printf("%e,",yBlastEia::Q[i]*1E8);
    printf("%e,",yBlastEia::Q[i]*1E12);
    printf("%e\n",yBlastEia::T_s[i]);}
  fclose(f);
}//~~~~~~YAGENAUT@GMAIL.COM~~~~~~~~~~~~~~~~~~~~~~~~~LAST~UPDATED~12SEP2013~~~~~~
```

Recreated EIA Figures 6-1, 6-2, & 6-3







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